Cortical Control of Neural Prostheses

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by

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Work Performed During Reporting Period

Since beginning our study of microwire recording electrodes, we have implanted chronic electrode arrays in 11 macaque hemispheres. These electrodes have consisted of either 50 micron stainless steel teflon-coated wires manufactured by NB labs or 50 micron polyimide-coated tungsten wires. These are configured into arrays of 2x8 or 2x11 with typical inter-electrode distances. Although excellent results have been obtained in our guinea pig cerebral cortex experiments, our ability to record single units in the macaque has been disappointing. A typical pattern has emerged when reviewing the relatively large number of primate implants we have carried out to date. Typically three arrays are implanted per surgery. Although we may see units during the implant procedure, these units disappear within three days of surgery. Units then tend to become recordable two to six weeks after the implant and are evident for several months thereafter. Unfortunately, most of the units we recorded were about 30-40 microvolts in amplitude and units are recorded on only one of the three arrays placed in each hemisphere. Usually, the 16-wire array that is picking up the units will have recordable spikes on only five wires. There are several possible explanations for this. The electrodes may not be inserted to the optimal depth; the tips of the electrodes are irregularly shaped or relative movement between the electrodes which are fixed to the skull and the brain may be injuring the peri-electrode tissue. We are presently developing a series of technological changes to address these issues. First we will report the results of the three implants carried out this quarter and then describe the new approaches we are presently pursuing.

The first implant of the quarter took place on Jan. 7th. Three arrays were placed in the left frontal cortex of Monkey F. Two of the arrays consisted of tungsten wires and one was stainless steel. They were lowered to depths of 2.7, 2.7 and 3 mm respectively. By Feb. 20, the first array was picking up 8 units. This was the maximum number of units recorded and they were all present only on this array. Six units are still evident three months later.

The next monkey (G) was implanted on the left side, Jan. 21st with three stainless steel arrays. These were at a depth of 1.8, 2.1 and 2.5 mm. Only the deepest array picked up units. On Feb. 2 we recorded 11 units from this array. By the first week in April we were still recording 4 units from this array.

The most recent implant was performed on April 1st . Monkey F received three arrays, two 22- wire tungsten arrays and one 16-wire stainless-steel array were inserted to a depth of 2.8, 2.8 and 3.0 mm respectively. Six units were recorded on one of the tungsten arrays April 24th. We expect a few more units to appear in the next several weeks.

The first issue we are addressing is correct insertion depth. We would like to place the recording tips in layer V of motor cortex to record extracellular potentials from large pyramidal cells. Because this layer varies in depth by 1.5 mm in different parts of the motor cortex it is difficult to know without recording, where this layer is located. During implantation we have not always been able to record spontaneous activity consistently. This may be due to the anesthetized state of the animal, to local tissue damage on insertion or to the low impedance of the non-encapsulated recording tips. We are addressing this issue in two ways. A microdrive capable of moving the recording arrays has been designed and is now being fabricated. This consists of a screw and holding post with a cantilevered arm that will be glued to the wire array. The wires will move through a template on a pressor foot place over the cortical surface. The pressor foot-microdrive unit will be cemented in place so that the foot fits flush with the trephine hole in the skull. This will make it possible to move the array a small amount on a daily basis to optimize the recording location of the array in the vertical (radial) dimension. Secondly, in the next surgery, we will be placing an antidromic stimulating electrode at the base of the ipsilateral pons to activate pyramidal tract fibers. Array placement will be optimized by inserting it to the depth that maximizes the antidromic field. This will alleviate the reliance on spontaneous activity to guide the electrode placement.

Electrode tips will be shaped and/or beveled with a YAG laser. With this device, we hope to smoothly cut the metal without damaging the insulation. We will also attempt to etch the tips electrolytically. The electrodes will the be re-insulated with either epoxylite or teflon in a vapor deposition chamber.

Finally, we are testing and developing new types of electrodes that will float on the cortical surface with minimal tethering forces. We are testing the Utah silicon array (10x10 array), initially in acute experiments recording units from cat auditory cortex. This experiment will be followed by a chronic implant in a macaque. Presently, Dick Normann at the University of Utah has fabricated a new array with shanks of 2 mm which are 400 microns longer than the older style. It is still not clear how many leads will be connected to the chronic array, although we now have the capability of wire bonding our own leads. Furthermore, Dr. Patrick Rousche, a graduate of Dr. Normann's program who has been instrumental in developing and testing the arrays has joined us in Arizona as a postdoctoral fellow in Dr. Kipke's lab. We are also developing a set of microwires attached to a platform that will float on the cortex. Very fine wires will serve as leads to an external connector. Both of these probes are designed to minimize tethering forces by the configuration of thin leads between a platform that floats on the cortical surface and a connector mounted on the skull.

Work Anticipated for the Next Reporting Period

In the next reporting period, we expect to continue to train the animals and to implant at least two more hemispheres. We will use either the improved microwire arrays or the chronic Utah electrode assembly. In addition, we will continue our work in refining strategies for controlling robotic arms using either real or simulated neuronal population responses from motor cortex.